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EFFECT OF SEBS ON IMPACT STRENGTH AND FLEXURAL MODULUS OF POLYSTYRENE/POLYPROPYLENE BLENDS

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Abstract. Blends of Polystyrene (PS) with Polypropylene (PP) were developed with the objective to overcome the inherent brittleness of PS and enhance the impact strength at room temperature. However, the blends of PS and PP were known to be immiscible. Previous studies have concluded that the block copolymer such as styrene-b- (ethylene-co-butylenes)-b-styrene (SEBS) is good compatibiliser for this PS/PP blends. The present study investigates the use of SEBS as a compatibiliser in this immiscible blend system. Using a Brabender PL2000 twin-screw extruder, blends of PS/PP in various composition range of 90-60 wt% PS containing different amount of SEBS in the composition range of 5-25 phr were prepared and injection molded to evaluate for mechanical properties. The results obtained from mechanical properties show some improvement in the properties of the blends indicating some compatibilisation effect in the blend system. The addition of SEBS enhanced the impact properties of the blends but reduced the flexural strength and flexural modulus. The blends of 90/10 PS/PP with 25 phr SEBS gave superior impact properties. Interestingly, the results show that SEBS is more effective at lower PP content.

Keywords: PS; PP; SEBS; mechanical properties; polymer blends

Abstrak. Pengadunan polistirena (PS) dengan polipropilena (PP) dibangunkan dengan objektif untuk mengatasi masalah kerapuhan PS dan meningkatkan kekuatan hentaman pada suhu bilik. Walau bagaimanapun, pengadunan PS dan PP adalah tidak serasi. Kajian terdahulu menunjukkan bahawa ko-polimer blok seperti stirena-b-(etilena-co-butilena)-b-stirena (SEBS) adalah agen penyerasi yang baik bagi adunan PS/PP ini. Kajian ini juga menyelidiki kegunaan SEBS dalam meningkatkan keserasian adunan PS/PP. Mesin penyemperit skru berkembar Brabender PL2000, digunakan untuk melakukan adunan PS/PP pelbagai komposisi dalam julat 90-60% PS yang mengandungi kandungan SEBS yang berbeza dalam julat 5-25 phr, dan diacu-suntikan bagi menentukan sifat mekanikal. Keputusan yang didapati daripada sifat mekanikal menunjukkan peningkatan sifat adunan yang menunjukkan kesan penyerasian dalam sistem adunan. Penambahan SEBS telah meningkatkan kekuatan hentaman adunan tetapi mengurangkan kekuatan dan modulus lenturan. Adunan 90/10 PS/PP dengan 25 phr SEBS menunjukkan kekuatan hentaman yang unggul. Yang menarik, keputusan menunjukkan bahawa SEBS lebih berkesan pada kandungan PP yang rendah.

Kata kunci: PS; PP; SEBS; sifat mekanikal; adunan polimer

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1.0 INTRODUCTION

One of the main directions of development of polymers with the aim of imparting specific desirable properties in modern polymer is through blending. Polymer blends are popular forms of new thermoplastic engineering materials and constitute a rapidly changing field. Their growth rate is very significant and exceeds more than 10% which is a few times than that of the plastics industry on the whole [1]. Therefore, mixing two polymers together to produce blends is a well-established strategy for achieving a specified portfolio of physical properties, without the need to synthesies new polymers. The subject is vast and has been the focus of much work, both theoretical and experimental.

The continuing pressure to reduce costs, improve productivity, quality and variety, and the uses of plastic in most downstream processes has generated the research in polymer blends [2]. This technique can be used to improve several properties desired while retaining some of other properties. For both, the processor and the end user application the use of blends and alloy technology allows the "customising" of a polymer product to specific requirements, usually at a significantly lower cost than synthesising new materials [3].

Unfortunately, most polymers are immiscible from a thermodynamic point of view because the entropy contribution to the Gibbs energy of mixing is negligible. A method for improving interfacial interactions in polymer blends includes the uses of a suitable modifier, known as compatibilising agent. These compatabilisers are usually partially miscible with the particular components of the system, that is, they are either chemically identical or similar to the blend components [4]. Compatibilisation of blend components is thus, a major consideration when designing blends and is often the primary criterion for commercial success.

Blending of polystyrene (PS) with a wide range of polymers has been studied with the main motive to toughen the PS. PS has the advantage of being clear, hard, easily processed and low cost. However it suffers from brittleness even at room temperature. Polypropylene (PP) is a popular material, which has good strength and rigidity. It can be considered a tough material at room temperature. Many studies had been reported on PP/PS blends and the use of SEBS as compatibiliser [4-6].

In the present study, the blending of PS with PP is carried out with PS as the major component. SEBS was used as the compatibiliser ranging from 5 - 25 phr.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials

PS used in this study was general-purpose grade (GPPS HH-30). PP used was polypropylene homo-polymer TITANPRO 6531 with a specified melt flow index of 3.5 g/10 minutes . Both of these resins were originally in the form of extruded pellets.

The compatibiliser used in this study was thermoplastic elastomer SEBS (Kraton 1652G) (containing PS blocks (Mw = 7,500) and an EB mid-block segment (Mw = 37,500) and Hardness, Shore A, 30s : 75).

2.2 Preparation of Blends and Test Samples

Various compositions of non-compatibilised PS/PP blends and compatibilised PS/PP blends with SEBS were prepared in a twin-screw extruder. The compositions of the blends prepared in this study were listed in Table 1. Preparation of blends were accomplished in a Brabender PL2000 twin-screw extruder with L/D = 30 and D = 2.5 cm. Before that, pellets of PS, PP, and SEBS powder (Kraton 1652G) were mixed in a tumbler mixer for 5 - 10 minutes to form a uniform composition throughout the batch size. This uniformly mixed feed was then melt blend in a co-rotating twin-screw extruder.

The extrusion was conducted at a speed of 50 - 55 rpm. and at a barrel temperature of 190, 225, 230°C from feeding zone to die zone, respectively. The residence time of the blends in the extruder was kept at about 60 seconds by adjusting the extrusion rate. The compound was extruded via a twin, 4 mm rod-die. The extruded strands were then air-dried and pelletised. The blends were extruded and pelletised twice to allow good dispersion of the PP phase within the PS matrix. Impact bars and flexural specimens were injection molded on an Arburg Allrounder 750-310D. The impact specimens were notched (45°) to a depth of 2.6 mm.

2.3 Impact and Flexural Properties Measurements

Notched Charpy impact tests were performed on Ceast 6546 Pendulum Impact tester according to ASTM D256. Rectangular specimens of dimension ($3 \times 13 \times 125$ mm) with 2 mm deep triangular notches of 45° were used.

Flexural test was carried out according to ASTM D 790 in a three-point loading system. Flexural tests were carried out on a Universal Testing Machine (Lloyd UTM L1000S) at room temperature (25 ± 2°C). The specimens were moulded shapes by injection moulding. The depth of the specimen was the thickness of the material and the support span was 16 times the depth of the beam. Five tests were carried out for each blend sample.

3.0 RESULT AND DISCUSSION

3.1 Impact Properties

Figure 1 illustrates the notched Charphy impact strength of uncompatibilised and the blends of PS/PP/ SEBS. The results of PS and PP homopolymers are also shown as control. It can be seen that impact strength of PS is approximately half of PP. Generally, the impact strength values of the uncompatibilised PS/PP blends increase with

Table 1 Blends formulations

No	CODE	SAMPLE DESIGNATION Compositions		
		Rigid Component (%)		Compatibiliser (phr)
		GPPS (HH-30)	Homo PP (6431)	SEBS (Kraton 1652G)
1	Control-1	100	0	0
2	Control-2	0	100	0
3	Control-3	90	10	0
4	PS90-1	90	10	5
5	PS90-2	90	10	10
6	PS90-3	90	10	15
7	PS90-4	90	10	20
8	PS90-5	90	10	25
9	Control-4	80	20	0
10	PS80-1	80	20	5
11	PS80-2	80	20	10
12	PS80-3	80	20	15
13	PS80-4	80	20	20
14	PS80-5	80	20	25
15	Control-5	70	30	0
16	PS70-1	70	30	5
17	PS70-2	70	30	10
18	PS70-3	70	30	15
19	PS70-4	70	30	20
20	PS70-5	70	30	25
21	Control-6	60	40	0
22	PS60-1	60	40	5
23	PS60-2	60	40	10
24	PS60-3	60	40	15
25	PS60-4	60	40	20
26	PS60-5	60	40	25

increasing PP content. No significant improvement in impact strength of PS was observed upon addition of 10 and 20 % PP into the blends. A more significant increase was observed as the PP content increased from 20 to 40 %.

All the impact strength values of uncompatibilised PS/PP blends are lower than impact strength of PP. These result are in agreement with Radonjic [7]. He found that uncompatibilised 70/30 PP/PS has poorer impact strength compared with PP. The present study also found that impact strength values are lower than expected ideal additive behaviour. This result is in agreement with Mustafa *et al.,* [8] in their study on 80/20 PP/PS blend. Adewole *et al.,* [9] concluded that the lower impact strength of PS/PP blends is related to poor interfacial interaction due to incompatibility between PS and PP. They suggested that PS/PP blends have to be modified with the addition of rubbery toughening agents, such as an EPR or SEBS triblock copolymer.

The results also show that the impact strength increase upon the addition of SEBS at all PS/PP compositions. The increase of the impact strength can be explained in terms of better interfacial adhesion between PS and PP caused by the addition of compatibiliser. The presence of SEBS has changed the behaviour of PS/PP blends from brittle to ductile. This result is in agreement with the findings of previous work by Schwarz *et al.,* [10] on HDPE/ PS blend. They reported that brittleness of 75/25 PS/HDPE blend changed with addition of 5 % wt SEBS to such a blend.

The results also show that the effectiveness of SEBS in enhancing the blends also depends on the PP composition. For the 90/10 and 80/20 PS/PP blends, this effect is clearly seen upon above 10 phr addition of SEBS into the PS/PP blends. No improvement in impact strength was observed upon the addition of 5 and 10 phr SEBS. However, a significant improvement was observed upon the addition of above 10 phr of SEBS into the 70/30 and 60/40 PS/PP blends. Bartlett *et al*., [11] also found that the addition of 20 phr SEBS into PS/PP blends increased impact strength of the blends.

Figure 1 also indicates that below 15 phr SEBS content, the impact strength increases with increasing PP content within the range studied. However, for 20 and 25 phr SEBS content, the impact strength decreases with increasing PP content. For 10 and 20 % PP content, the impact strength increases nearly 4 times as the SEBS content increases from 15 to 20 phr, compared with only twice at 40 % PP content.

The interesting observation is for the blends containing 20 and 25 phr SEBS. Although the impact strength of 90/10 PS/PP blends is lower than 60/40 PS/PP blends, the blends of 90/10/25 PS/PP/SEBS blends is higher than 60/40/25 PS/PP/SEBS blends. For this blend, a linear decrease of impact strength occurred as the PP content increases from 20 to 40 %. Similarly, the impact strength of 90/10/20 PS/PP/SEBS blends are higher than 60/40/20 PS/PP/SEBS blends. Therefore, it can be deduced that SEBS is more effective at lower PP content. Similar findings have been obtained by Mustafa *et al.,* [8]. They found that in the PP-rich blends (80/20 PP/PS), small amount of compatibiliser (PPA) is more effective to enhance the impact strength of the blends. The results also

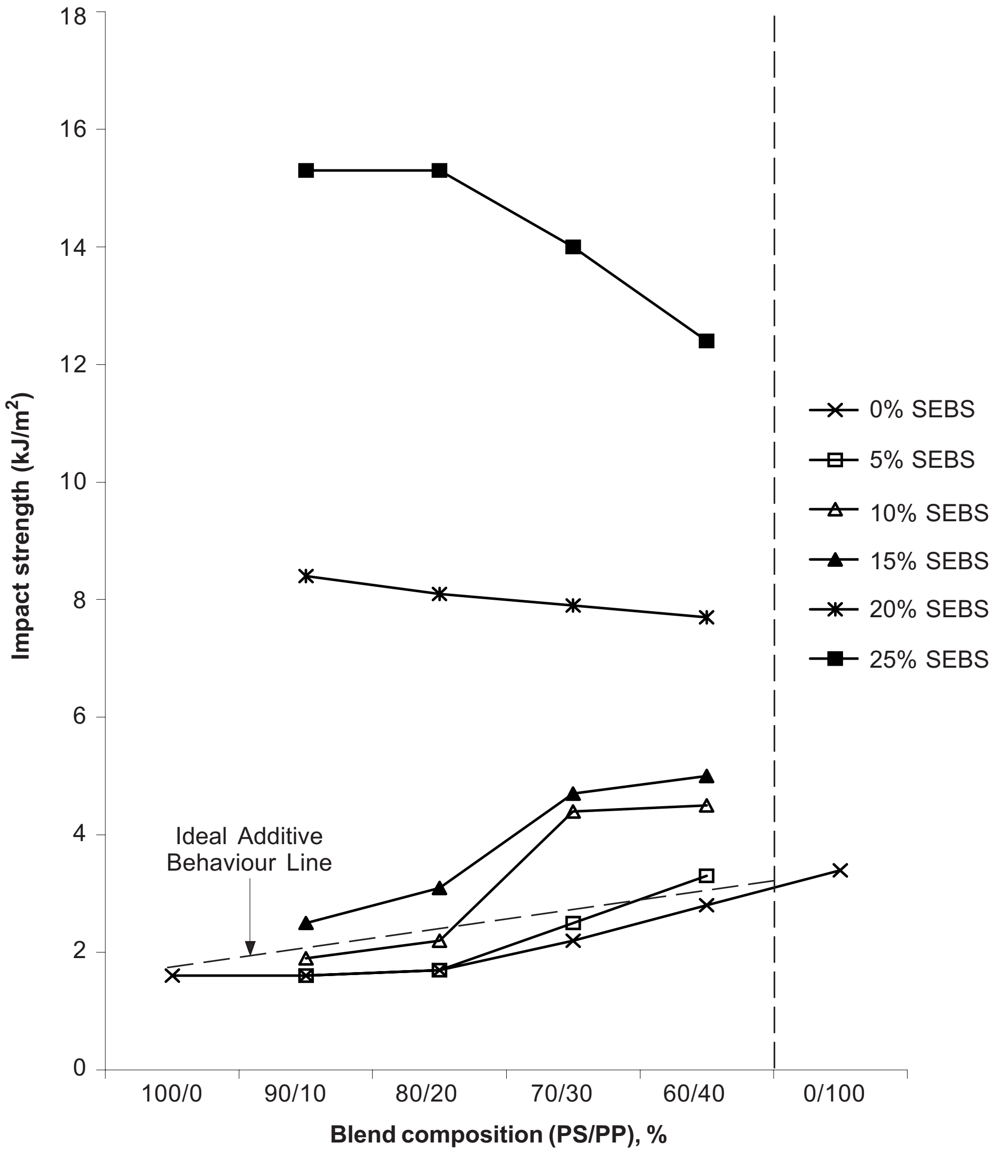

Figure 1 The impact strength of uncompatibilized PS/PP and PS/PP/SEBS blends

shows that the PS/PP blends with 20 phr and higher SEBS content are significantly higher than PP.

3.2 Flexural Modulus

The flexural modulus of uncompatibilised and the blends of PS/PP/SEBS are shown in Figure 2. The results of PS and PP homopolymers are also shown as control. This investigation on flexural properties of PS/PP blends revealed that the flexural modulus

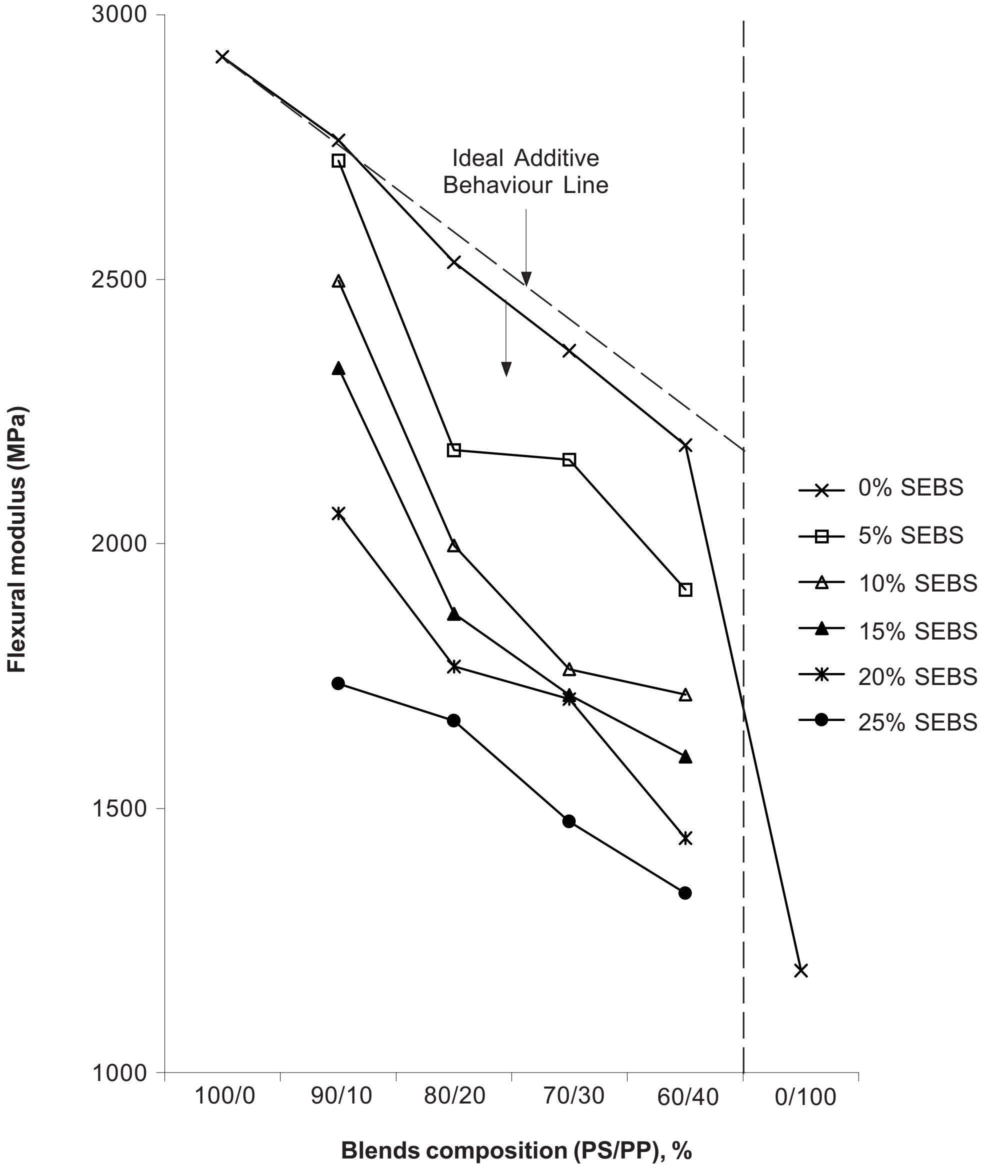

Figure 2 The flexural modulus of uncompatibilised PS/PP and PS/PP/SEBS blends

of all blends is between both of parent polymers. The flexural modulus of uncompatibilised PS/PP blends was found to be nearly the ideal additive behaviour line. The result obtained from this figure also shows that the flexural modulus of PS is 60 % higher than PP. A linear decrease of flexural modulus was observed as the PP content increased from 0 to 40 %.

The results also showed that the flexural modulus decrease upon the addition of SEBS at all PS/PP compositions. From Figure 2, a sharp drop of about 15 % was observed in the 80/20 PS/PP blends upon the addition of 5 phr SEBS. Overall, the drops of flexural modulus are quite similar for all blend compositions upon the addition of 25 phr SEBS.

According to Horak *et al.,* [12], the addition of compatibilisers leads to a slight decrease in modulus, as a result of increased elastomer concentration. Thermoplastic elastomers will usually lower the blend stiffness due to their elastomeric nature.

This investigation reveals the decrease of flexural strength and flexural modulus with increase in PP content. The results in previous section have shown that increasing PP contents will improve the ductility of the blends. Therefore, the results are in agreement with previous researcher, where an improvement in ductility is often accompanied with sacrifices in stiffness [10]. In two-phase systems, if the modulus of the dispersed phase is greater than the continuous phase, the modulus of the mixture will be greater than the continuous phase. Conversely, the modulus of the dispersed phase is lower than the continuous phase [13].

4.0 CONCLUSION

Significant improvement in compatibilisation of PS and PP was achieved through the use of SEBS. The evidences of compatibilisation were obtained from the impact properties. The result shows that adding SEBS to PS/PP blends improves the impact properties. The SEBS acts as an interfacial agent between the PS matrix and the dispersed PP particles. It lowers the interfacial tension and improves the interfacial adhesion. The results also show that the flexural modulus decreases upon the addition of SEBS at all PS/PP compositions. A sharp drop of about 15% was observed in the 80/20 PS/PP blends upon the addition of 5 phr SEBS. Overall the drops of flexural modulus are quite similar for all blend compositions upon the addition of 25 phr SEBS. However, continuous investigation especially on the rheological properties and crystallinity studies are necessary to successfully explore the true potential of such blends. Blending of PS with other rubbers can be a convenient way to increase the impact strength of PS.

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